An RF Antenna Integrated with a Solar Array for Spacecraft Application

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Reflectarray integration with a solar array

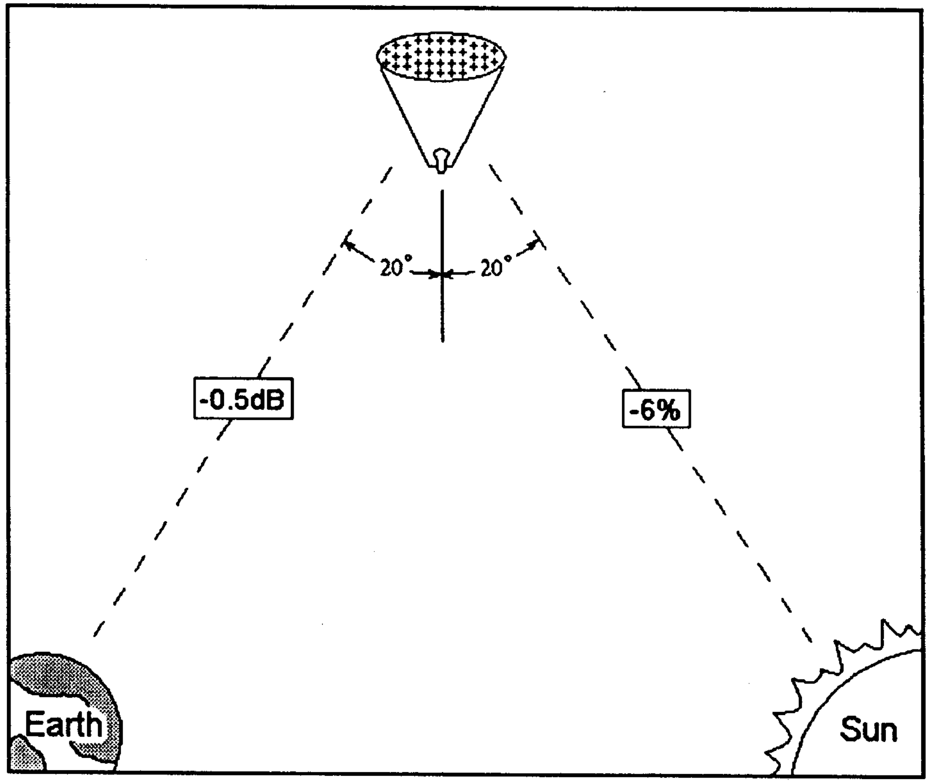
Introduction

- need for reductions in mass, size and cost of spacecraft
  - especially in era of smaller, cheaper spacecraft
- most spacecraft have two separate, and large, apertures for the antenna and the solar array
- large apertures require large support structures
- combining apertures would help meet above goals without significantly affecting the performance of either aperture
- would also facilitate spacecraft maneuvers, attitude control, and increase field of view of instruments

Reflectarray integration with a solar array

Introduction (cont'd)

- most deep space missions have Sun-Earth subtended angles of less than 40°
- losses could be regained by increasing area by approximately 6%



Goal: Develop an X-band integrated antenna/solar array

Reflectarray integration with a solar array

Antenna selection

- chose a microstrip reflectarray as the antenna aperture
- used thin crossed-dipoles as the radiating elements, which minimizes blockage of sunlight
- why a reflectarray?
  - reflectarray and solar array are both flat
  - reflectarray lays on top of the solar array
  - reflectarray illuminated by a horn, and does not require a power division network
- support structures for the reflectarray and the solar array can be combined, significantly reducing stowage volume

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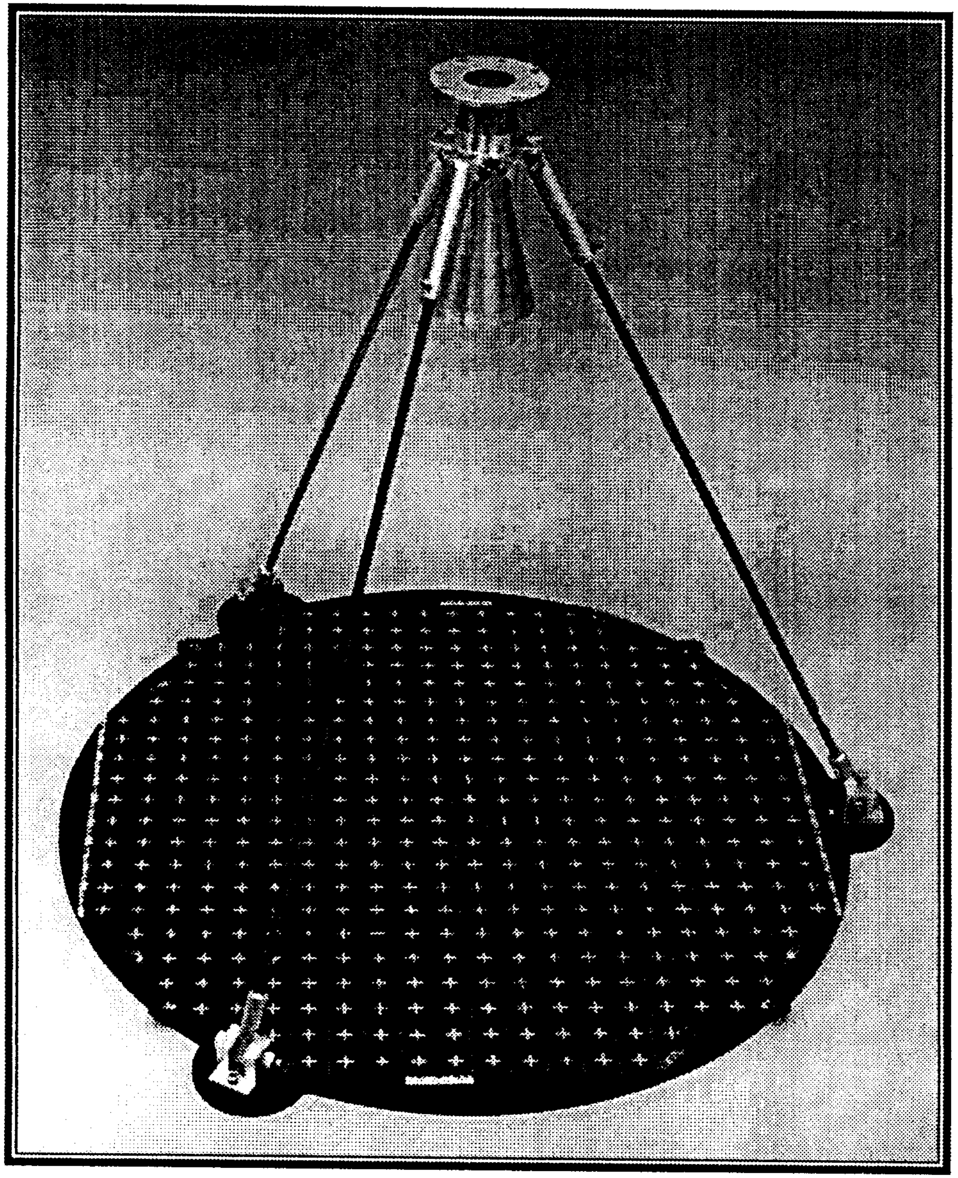
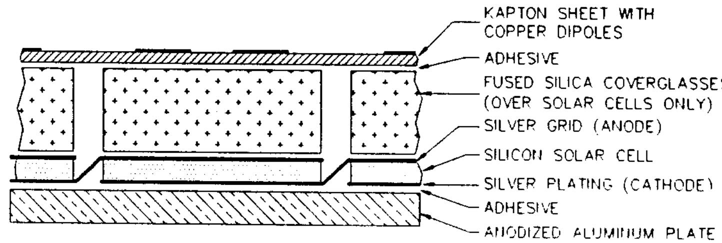
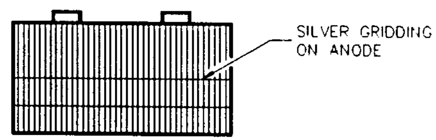
Spacecraft Antenna Research Group





CROSS-SECTION OF ANTENNA



TOP VIEW OF SOLAR CELL

- X-band, CP
- 0.5m diameter
- f/D = 0.75

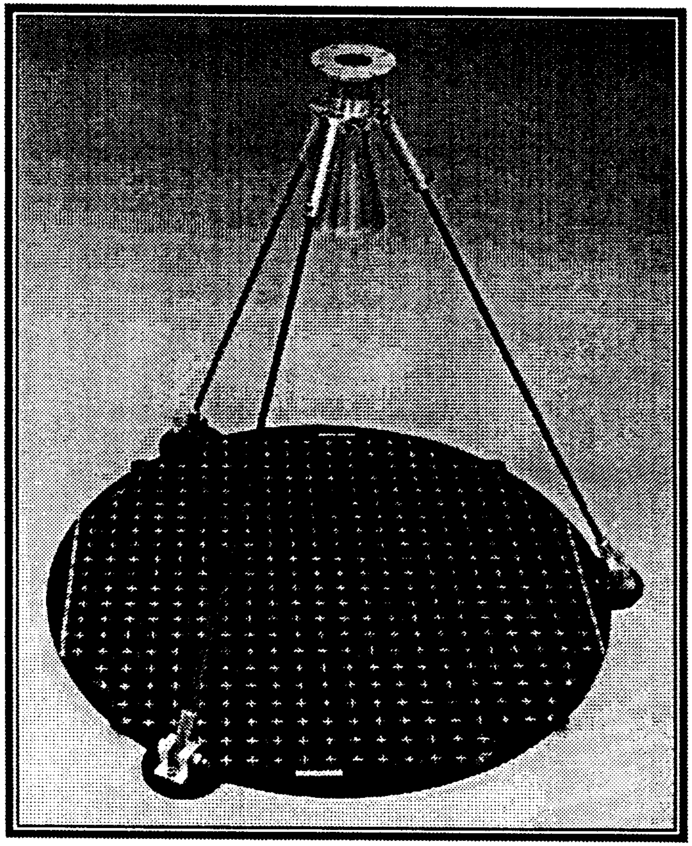
A reflectarray integrated with a solar array

5/10/2000

Reflectarray integration with a solar array

Antenna Description

- X-band, CP, 0.5m in diameter
- four components to final antenna:
  - mechanical support structure
  - an X-band feed horn
  - a solar array with 198 solar cells
  - Kapton substrate with 408 crossed-dipoles laid over solar cells
- element spacing fit to solar cell size
- supported by a 0.5m-diameter, 6.5mm-thick anodized Al plate
- feed horn:
  - HPBW of 39°, -9dB edge taper
- f/D = 0.75

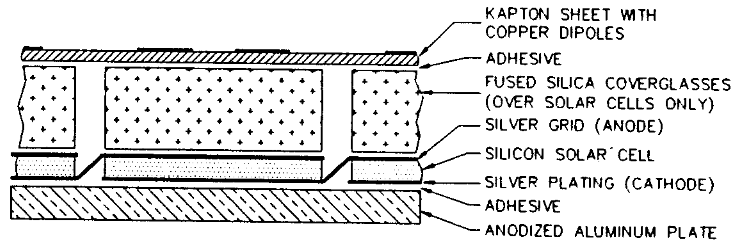


Photograph of integrated antenna

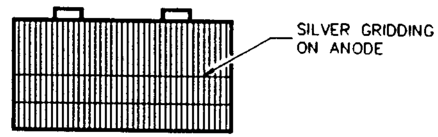
Reflectarray integration with a solar array

Solar Array Description

- 198 solar cells glued to anodized aluminum support plate
- fused silica coverglasses (1.52mm-thick) glued on top of solar cells
  - for protection in space environment
- coverglass also acts as substrate for reflectarray elements
- Kapton's orange color significantly reduces the intensity of light incident on the solar array but was used because of its availability
  - future versions would utilize a more optically transparent film



CROSS-SECTION OF ANTENNA



TOP VIEW OF SOLAR CELL

Cross-sectional and top views of solar cell

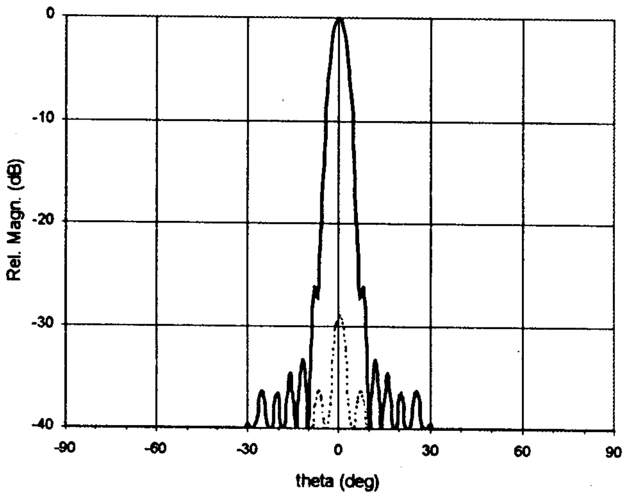
Reflectarray integration with a solar array

Method of analysis and assumptions

- MoM used to analyze reflectarray
  - software developed by D. Pozar, University of Massachusetts
- calculations neglected any effects of irregular ground plane and fused silica (coverglass) substrate
- designed and etched three versions for tuning
  - at desired $f_o = 8.4$GHz, and $f_o \pm 3\%$

Reflectarray integration with a solar array

Summary of calculations



Calculated pattern

Gain = 30.4dB

η = 59%

3dB Gain Bandwidth = 3%

Reflectarray integration with a solar array

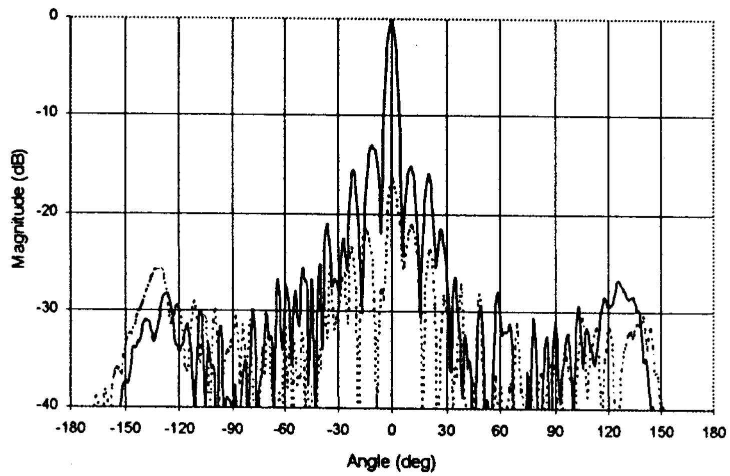
Solar array results

- very encouraging
- Kapton membrane alone (no dipoles) reduced solar array power output by 40.5% from the no-Kapton reference
  - optically clear membrane was available but harder to get
- addition of crossed-dipoles reduced power a further 10%, which was the expected loss from a clear membrane
  - lost power could be regained by increasing the solar array area by 10%, or by increasing the diameter by only 4.9%
  - this increased area is a small amount considering the added benefits of reduced mass and volume

Reflectarray integration with a solar array

Reflectarray results

- news for the reflectarray was encouraging, but not as good as for the solar array
- reflectarray did form a coherent beam, but...
- ... the efficiency was only about 10%, far from the expected value of about 40%



Gain = 23dB

Cross-pol ≤ -16dB

η = 10%

Reflectarray integration with a solar array

Discussion

- solar array performance was very promising
  - need to use an optically clear film for reflectarray elements
- possible factors contributing to the low antenna efficiency:
  - inhomogeneous ground plane and substrate not well-understood
  - is there a better choice for the reflectarray element?
- future work would focus on the above areas

Reflectarray integration with a solar array

Conclusion

- demonstrated that the integration of a large antenna with a solar array is highly feasible
- the integration of the antenna and solar array apertures would substantially reduce total spacecraft mass, volume, and launch cost
- further work on details is required to improve efficiency

Reflectarray integration with a solar array

Acknowledgements

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References

J. Huang, "*Capabilities of Printed Reflectarray Antennas*", IEEE Phased Array Systems and Technology Symposium, Boston, Massachusetts, October 1996, pp. 131-134

D. M. Pozar, "*Reflectarray Antenna and Solar Array Integration for Spacecraft Applications*", University of Massachusetts at Amherst, Final report prepared for JPL, March 1997